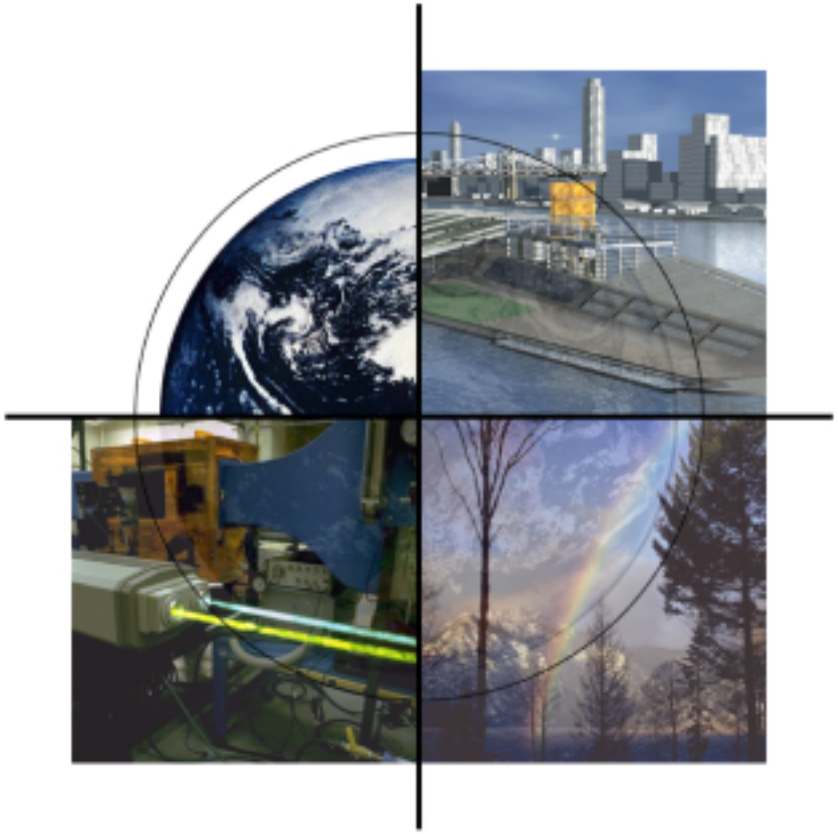
FutureGen – Electricity, Hydrogen and Carbon Sequestration from Coal

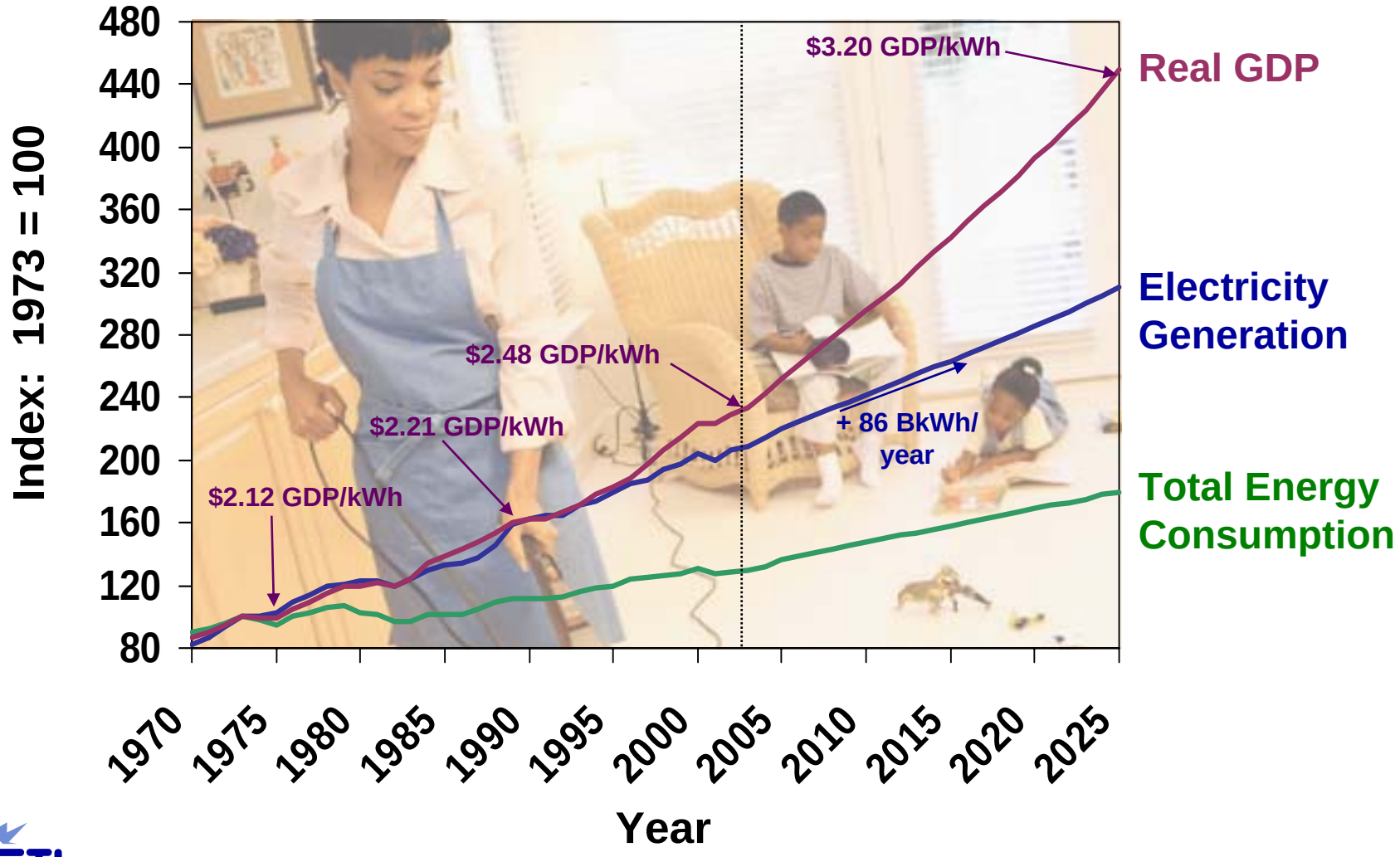


SECA Annual Workshop and Core Technology Program Peer Review

Boston, MA
May 11, 2004

Mike Eastman, Technology Manager
National Energy Technology Laboratory

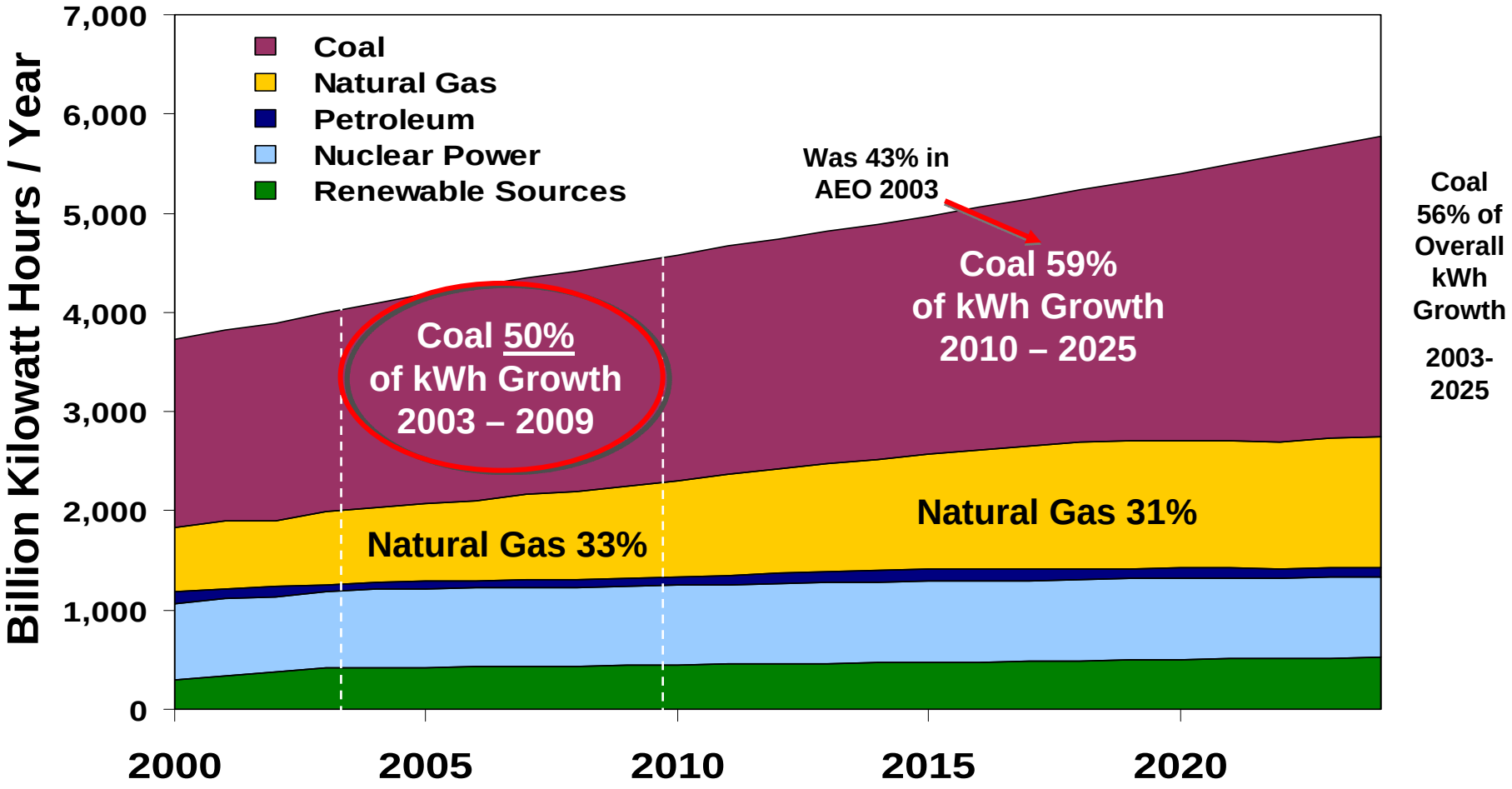
Energy Use Compared to Economic Growth



MLE-SECA-051104

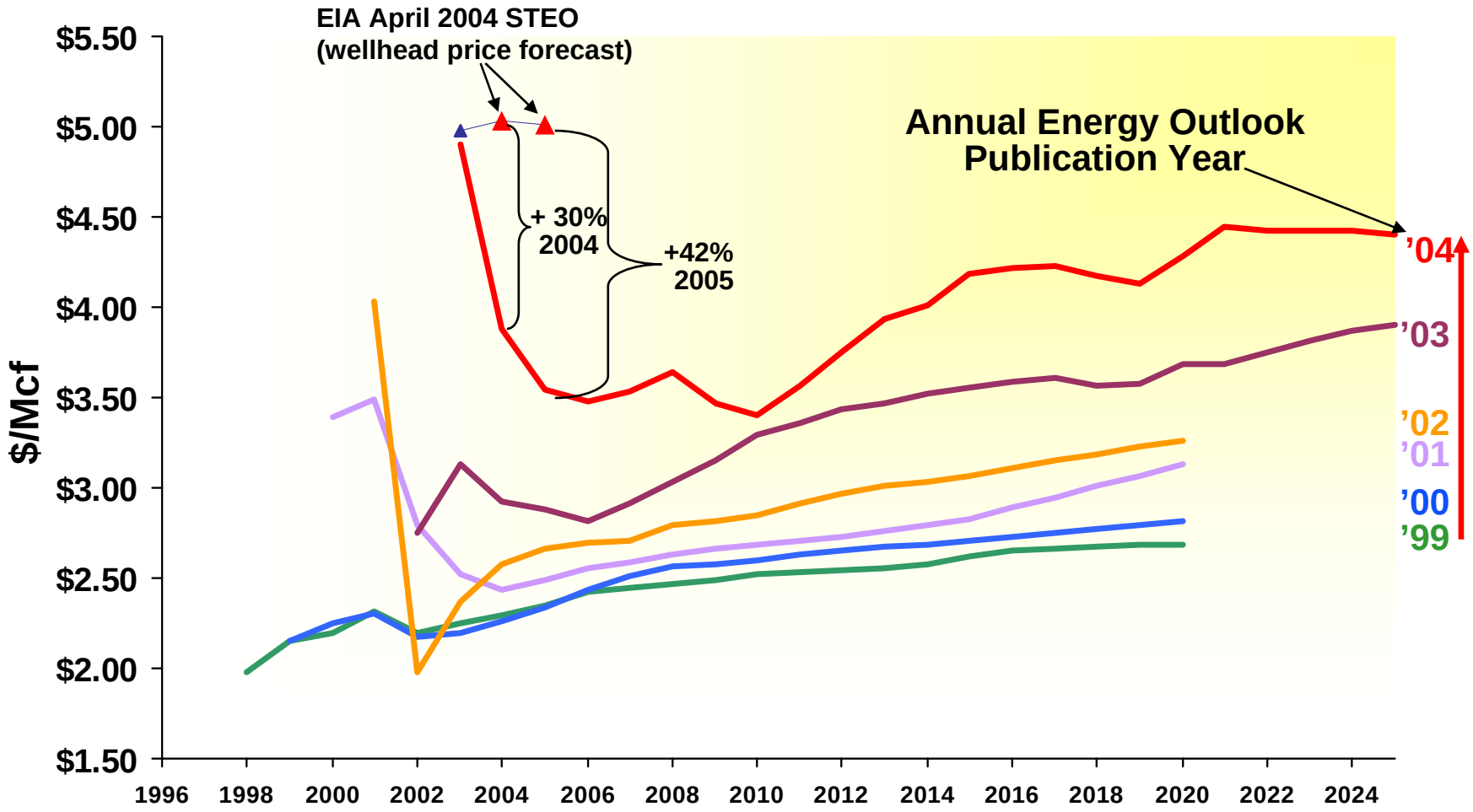
GDP: History - U.S. DOC, Bureau of Economic Analysis; Forecast - Annual Energy Outlook 2004
Energy & Electricity: EIA, Annual Energy Review 2002; Annual Energy Outlook 2004

Fuel Mix for Electricity Growth AEO'04



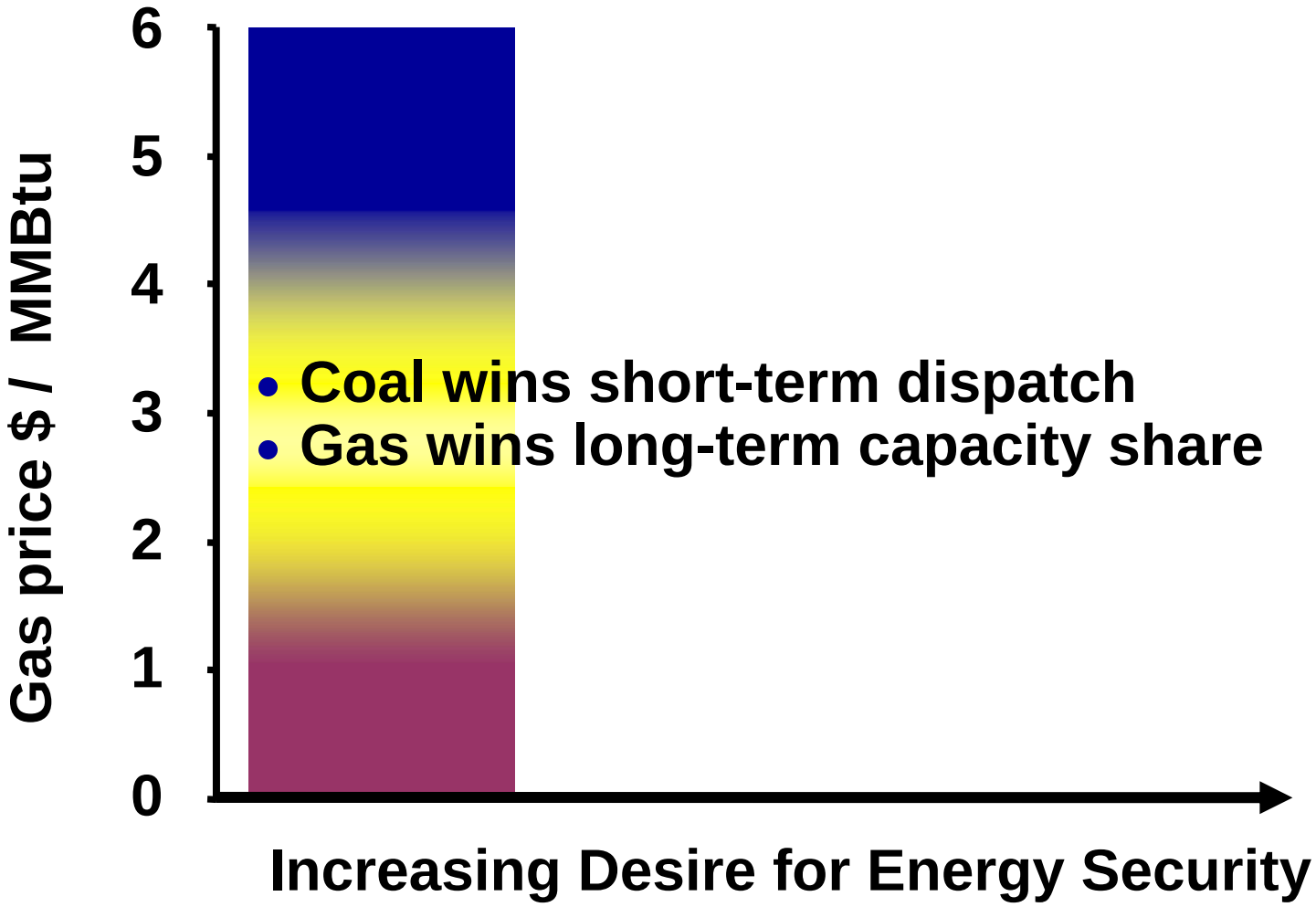
Coal Expected To Provide 50% of Incremental kWhs (2003 to 2009) Despite Few Additions

Increasing Natural Gas Price Forecasts



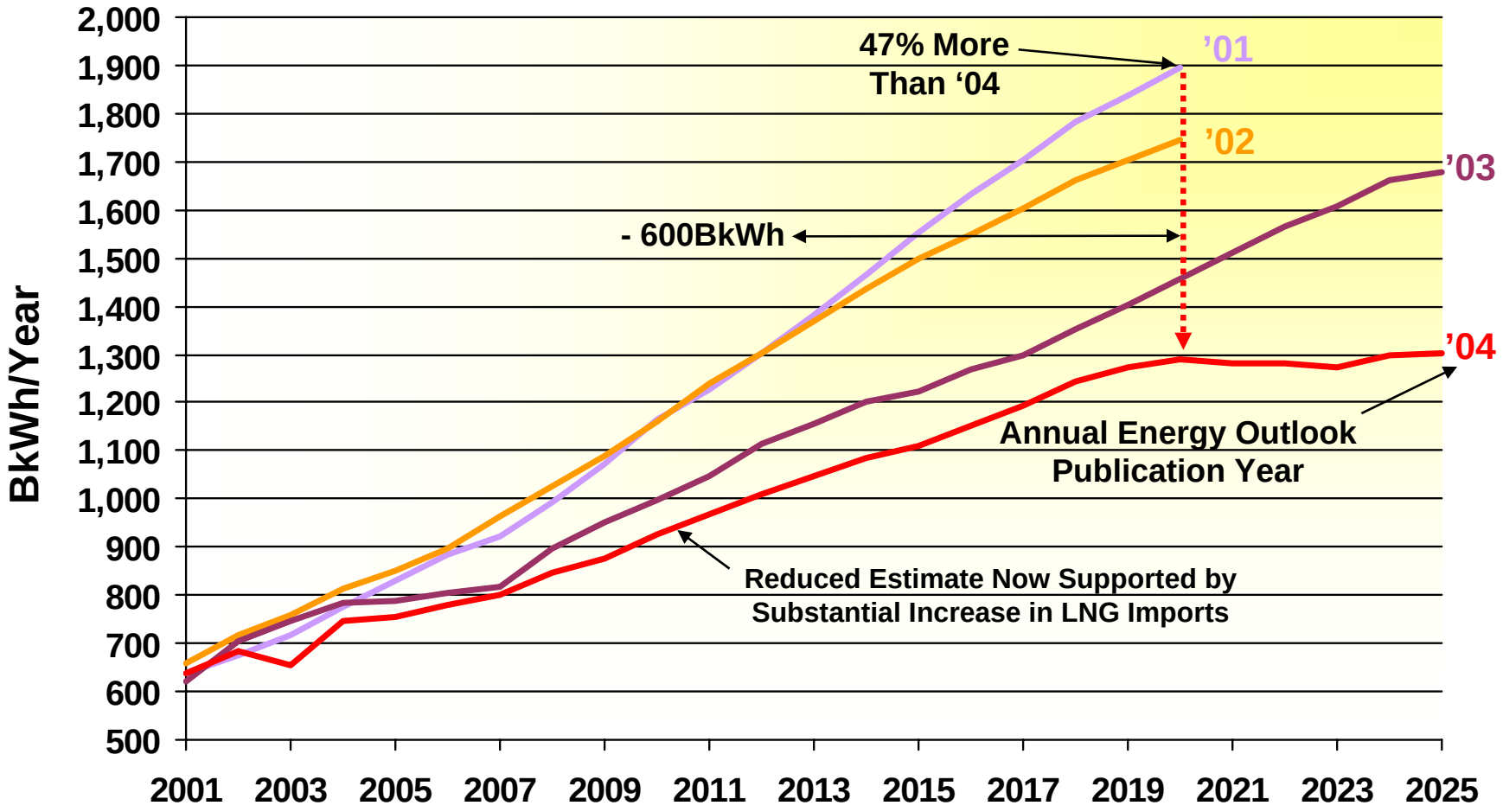
AEO 2004 Natural Gas Price Forecasts
(Short-term forecasts indicate higher prices)

Natural Gas / Coal Competition



Changing Natural Gas Generation Forecasts

Paradigm Shift in Fuel Use for Electricity

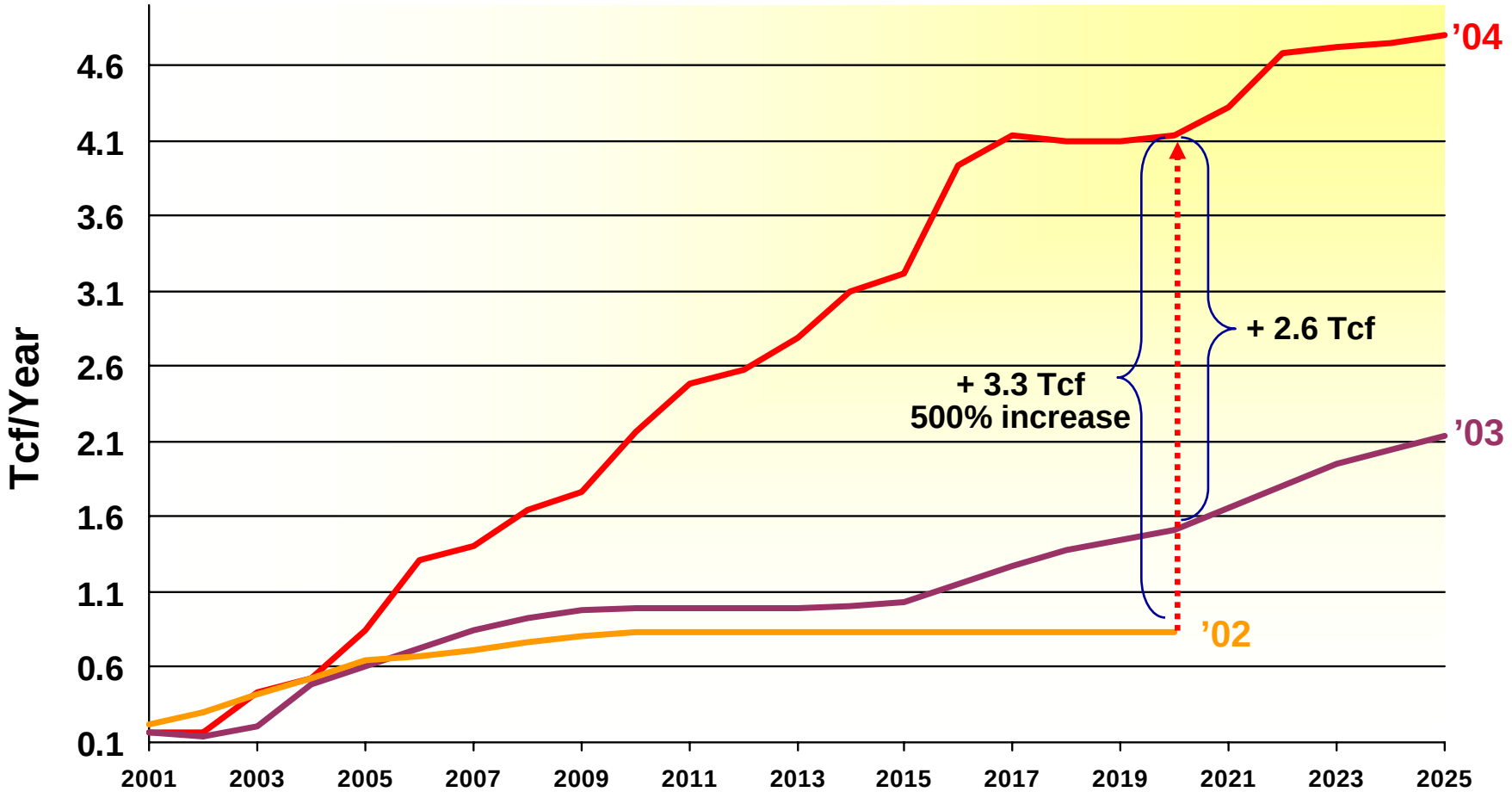


Gradual Recognition of Natural Gas Supply Constraints

Three Year Decline (2020) Nearly Equal to Today's Gas kWh Production

Changing LNG Import Forecasts

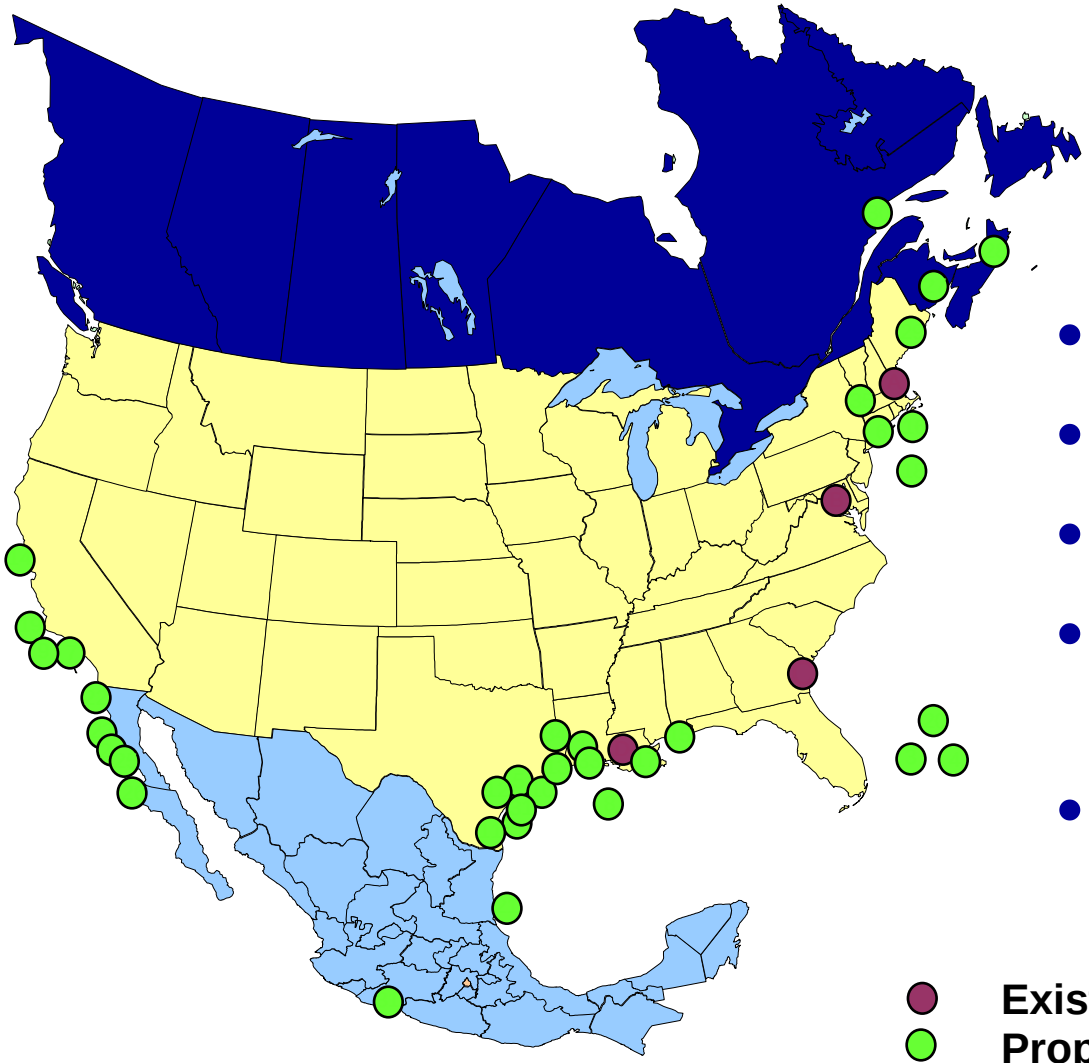
Shift in Imported Fuel for Gas-fired Generation



Rapid Increase in LNG Supply Assumption Supports Natural Gas Generation Potential

Annual Energy Outlook 2002, 2003 and 2004

North American LNG Regasification Terminals



- 4 existing terminals
- 32 active proposals
- 15 Tcf if all built
- None under construction
- 7-year construction

FERC, December, 2003

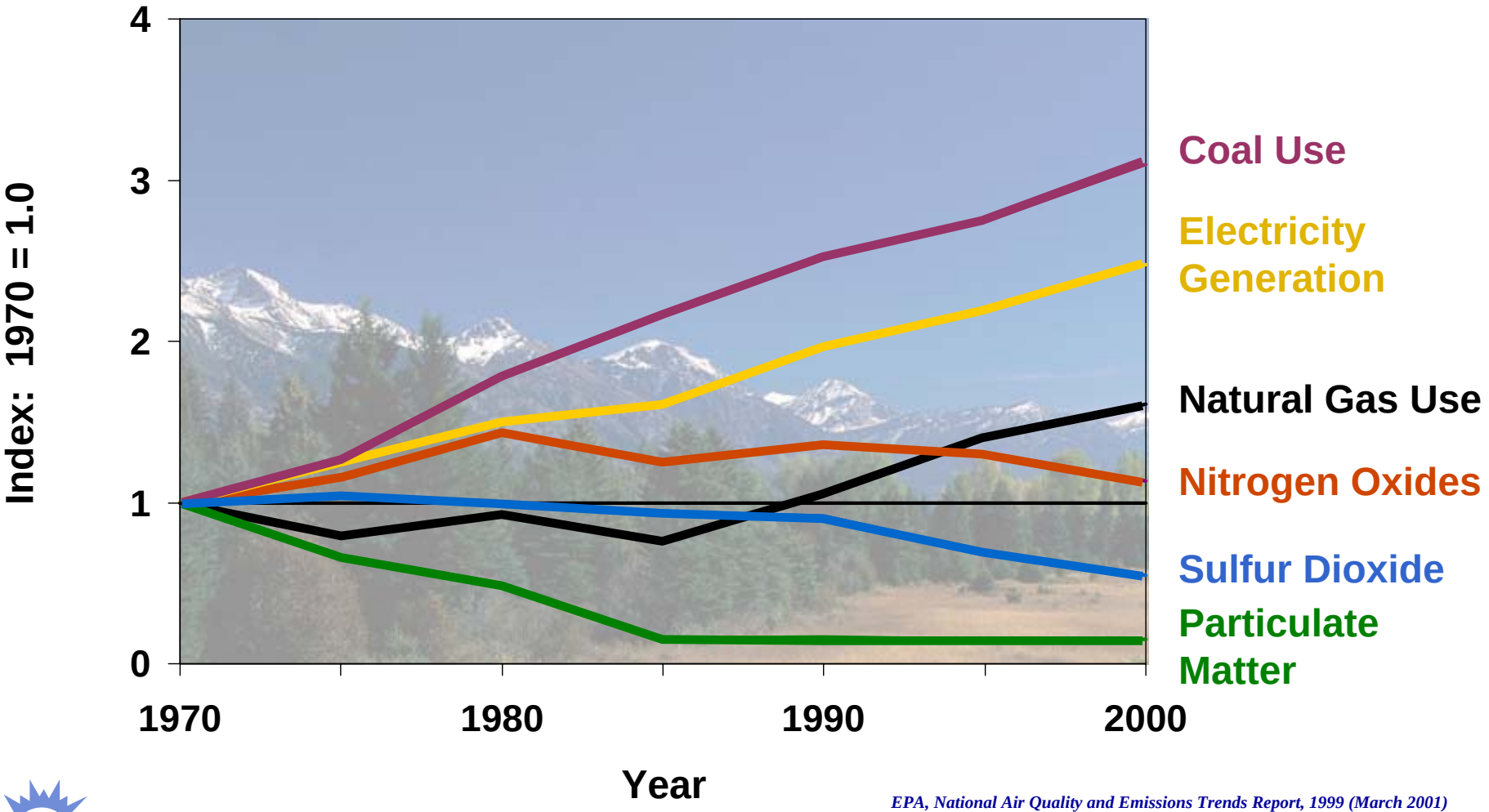
Dramatically Changed Perspectives On Infrastructure Security

Tanker Docked at Everett, Massachusetts

Is It Safe?, Boston Globe, July 27, 2003

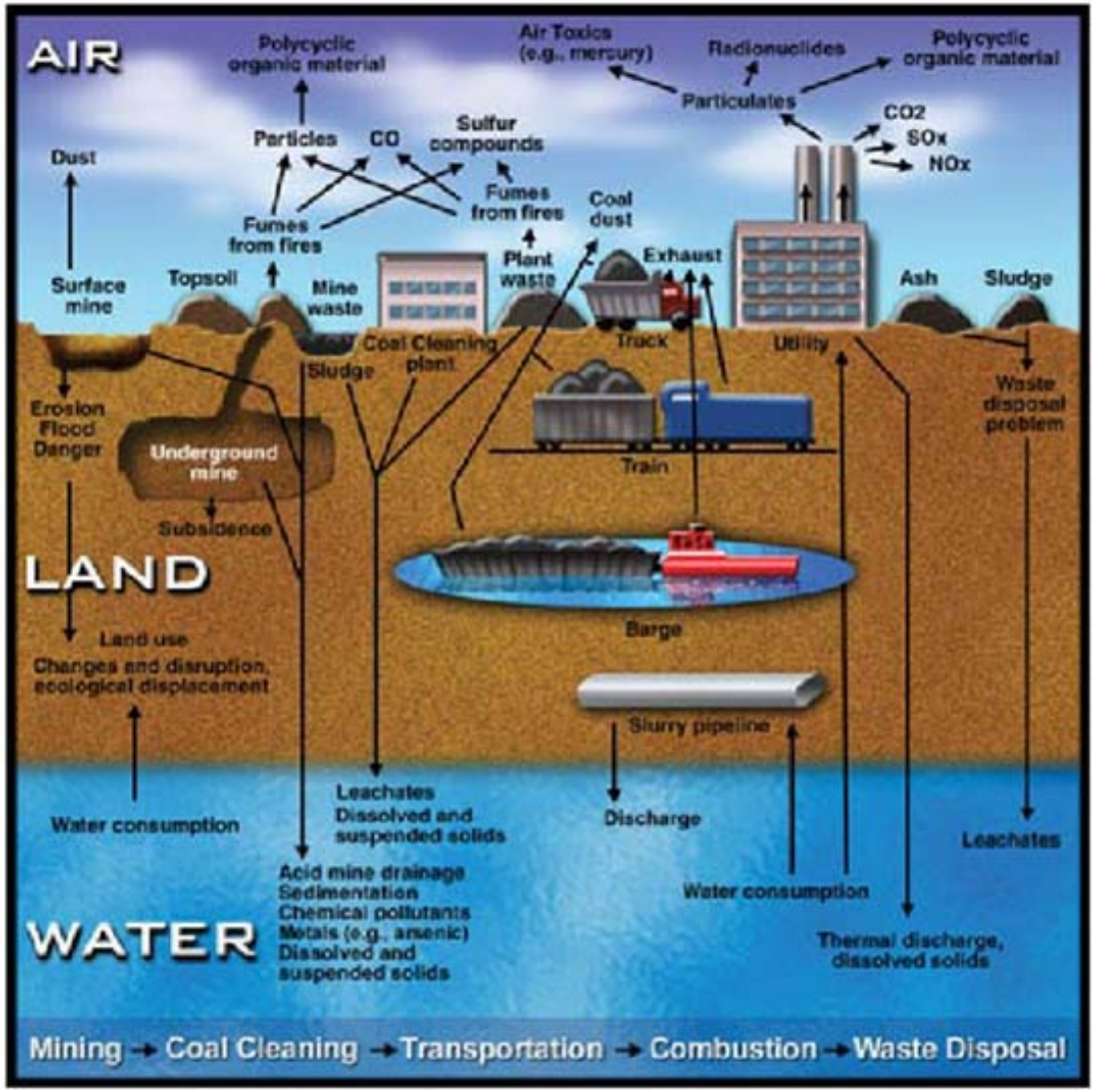
Contaminant Emissions Down Sharply

U.S. Power Plants



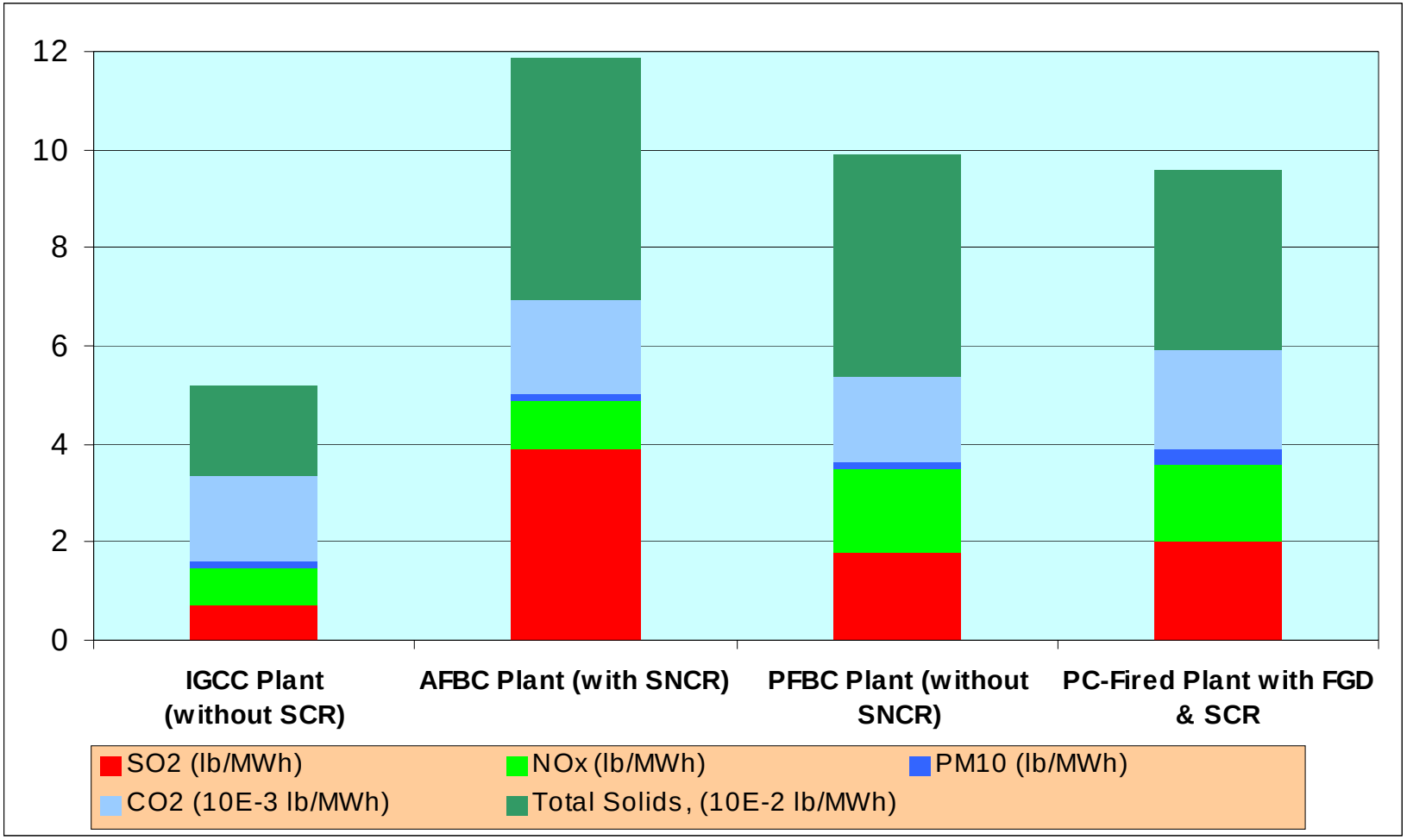
EPA, National Air Quality and Emissions Trends Report, 1999 (March 2001)
DOE, EIA Annual Energy Review

Broad Environmental Concerns About Coal

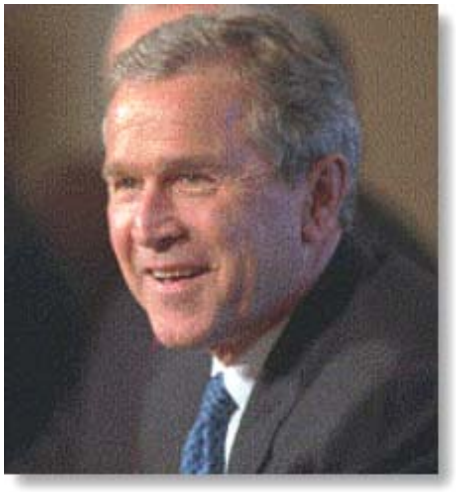


Cradle to Grave: The Environmental Impacts from Coal, Clean Air Task Force, Boston, MA,June 2001

Comparison of Emissions Between IGCC and other Coal-Fired Technologies



Presidential Initiatives



February 27, 2003

FutureGen Initiative --"…the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant …"

January 28, 2003

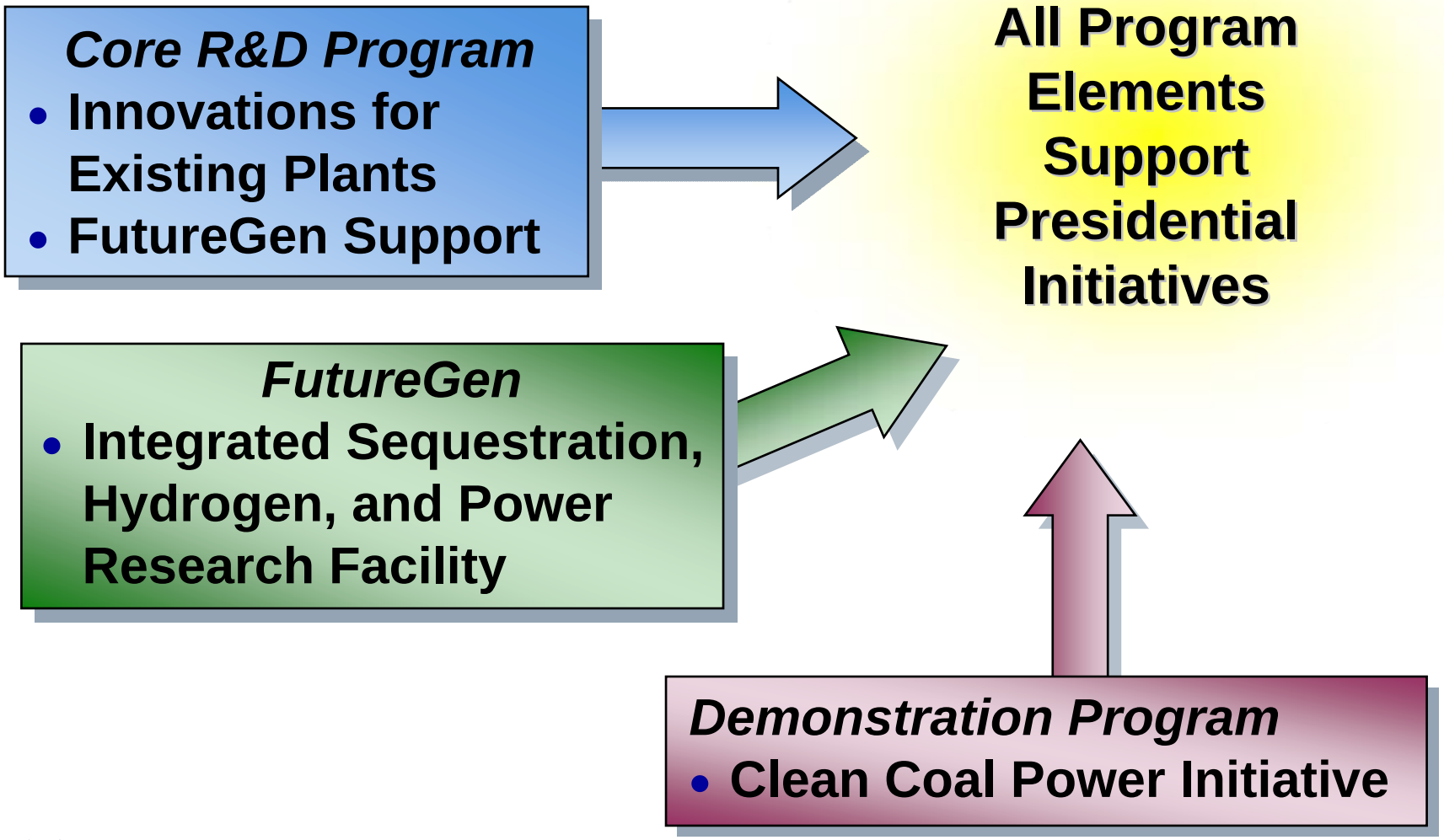
Hydrogen Fuel Initiative – "Tonight I'm proposing $1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles."

February 14, 2002

Clear Skies Initiative -- calls for "… new tough standards to dramatically reduce the three most significant forms of pollution from power plants, sulfur dioxides, nitrogen oxides, and mercury."

Climate Change Initiative – "will set America on a path to slow the growth of our greenhouse gas emissions and, as science justifies, to stop and then reverse the growth of emissions."

Elements of Coal & Power Program



Clean Coal Technology Roadmap Addresses Near- and Long-range Needs

- **Short-term: existing fleet**
  - Cost-effective environmental control technologies to comply with current and emerging regulations
- **Long-term: future energy plants**
  - Near-zero emissions power and clean fuels plants with CO_2 management capability

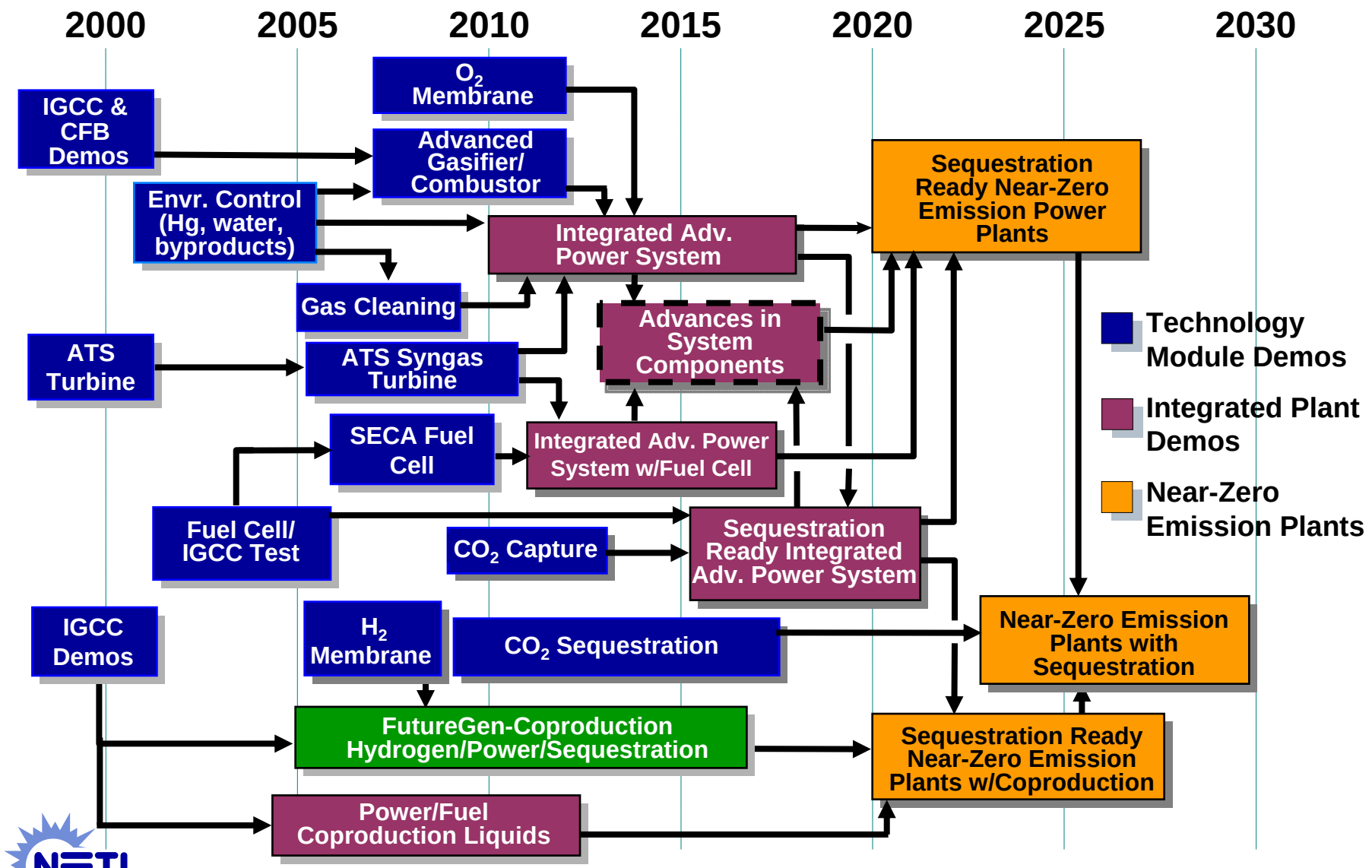
Can be found on CURC website

www.coal.org

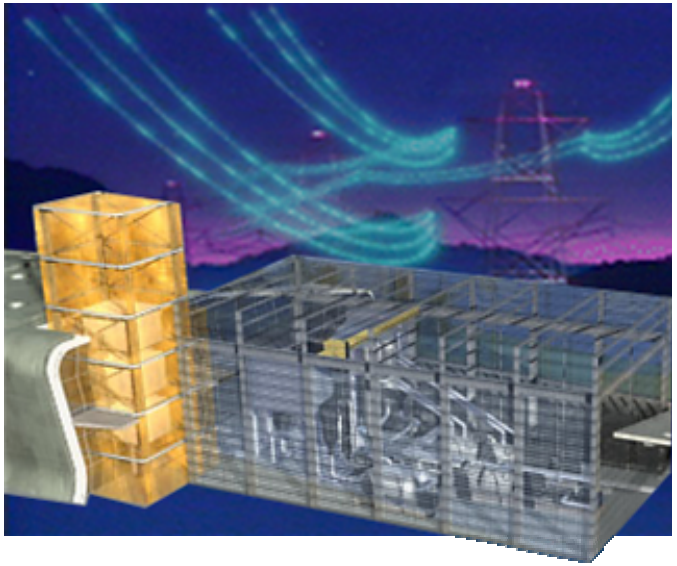
and NETL

www.netl.doe.gov/coalpower

Technology Roadmap – Future Energy Plants



FutureGen Project Description



World's first near-zero emission, coal-based power plant to:

- ✓ *Pioneer advanced hydrogen production from coal*
- ✓ *Emit virtually no air pollutants*
- ✓ *Capture and permanently sequester carbon dioxide*
- ✓ *Integrate operations at full-scale – a key step to proving feasibility*

Goals

1) Operate a full-scale (275 MW) integrated research plant
2) Capture >90% of CO_2 and permanently sequester (1 million tons/year)
3) Prove effectiveness, safety and permanence of CO_2 sequestration
4) Test and validate cutting-edge technologies in "living laboratory"
5) Push toward Clean Coal Technology Roadmap 2020 near-zero emission targets

NETL

Why *FutureGen* Is Needed

- ***FutureGen* is a key step to creating a zero emission coal energy option**
- ***FutureGen* will enable us to:**
  - Meet our growing energy needs with zero-emissions coal
  - Secure this country's economic and energy future through the clean use of coal, our most abundant, strategic, domestic energy resource
  - Remove all environmental concerns over coal's use including climate change concerns by sequestering carbon dioxide emissions from coal power plants, and
  - Produce clean low-cost hydrogen with zero emissions for power generation or for transportation
- **Integration of concepts and components is the key to proving the technical and operational viability**

Geologic Sequestration Highlights
(1 Million TPY CO_2, ~ 100 MW Coal Power Plant)

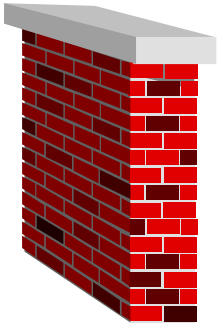
Weyburn CO_2 EOR Project

- Pan Canadian Resources
- 200-mile CO_2 pipeline from Dakota Gasification Plant
- 130M barrels oil over 20-year project
- $28M

Sleipner North Sea Project

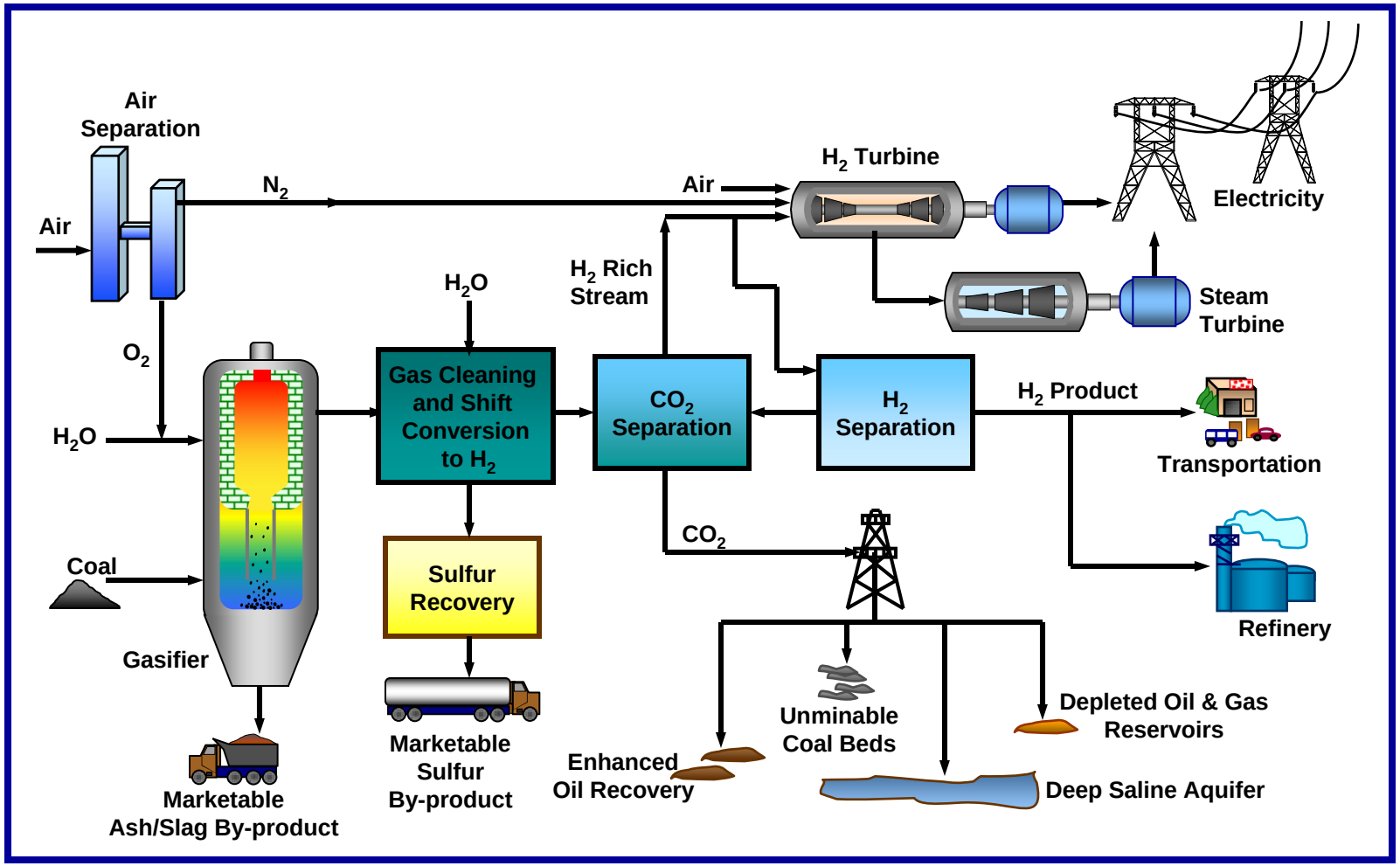
- Statoil
- Currently monitoring CO_2 migration
- $80M “incremental cost”
- $35/ ton CO_2 tax

Sequestration R&D



- **Barrier Issues**
  - Health, safety and environmental risks
  - Permanence and large scale verification
  - Capacity evaluation
  - Infrastructure
  - Uncertain regulatory frameworks
  - Protocols for identifying amenable storage sites
- **Pathways**
  - Depleting oil reservoirs
  - Unmineable coal seams
  - Saline formations
  - Enhanced terrestrial uptake
  - Ocean fertilization and injection
  - Regional Partnerships

FutureGen Flow Diagram



Hydrogen From Coal --- Objectives

- ***Production: Central Pathway ---*** **By 2015, demonstrate a 60% efficient , zero emissions, coal-fueled hydrogen and power co-production facility that reduces the cost of hydrogen by 25% compared to current coal-based technology (~$6/MM Btu)**

- ***Production: Hydrocarbon Pathway ---*** **By 2010, complete tests and evaluations of most promising hydrogen-rich, coal-derived liquids for reforming applications**

- ***Storage ---*** **By 2015, work with other DOE Offices to develop safe, affordable technology capable of storing 9 wt. % hydrogen**

- ***Utilization ---*** **By 2010, complete tests & evaluations of H2/natural gas mixtures in modified and advanced internal combustion engines**

Hydrogen Production --- Technology Hurdles

- ***Production…****Gasifier Reliability, Air Separation Cost and Efficiency, Hydrogen Separation Cost and Efficiency, Co-Production Process Integration, Multi-contaminant Gas Cleaning, Syngas Convresion reactor Design and Performance, Catalyst-Wax Separation*

- ***Storage…****Materials*

- ***Utilization:*** *H_2/natural gas combustion in ICEs, Performance and emissions control*

- ***Process Engineering:*** *Process Intensification*

- ***CO2 Sequestration*** *– Capture and sequester impact on cost of cost of electricity, MMV*

FutureGen Technology Developments & Challenges

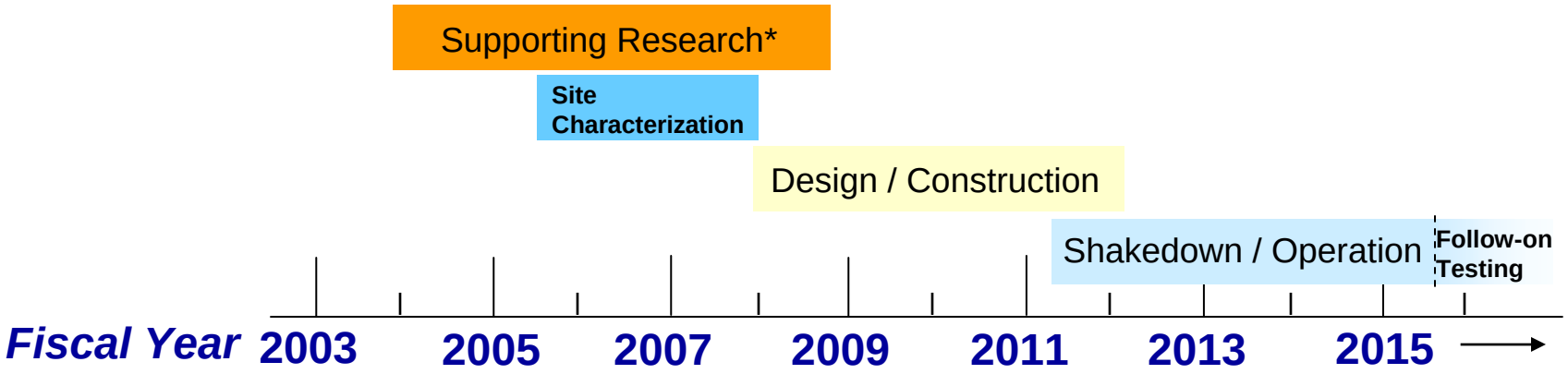
Traditional Advanced Technology		Research Inventions
Cryogenic Separation	→	O_2 Membranes
Amine Scrubbers	→	Hydrogen Membranes
Amine Scrubbers	→	"Clathrate" CO_2 Separation
Gas Stream Clean-Up	→	"Dirty" Shift Reactor
Syngas Turbine	→	Hydrogen Turbine
Fuel Cell ($4,000/kW)	→	SECA Fuel Cell ($400/kW design)
EOR based	→	Sequestration Technology
Existing Gasifier	→	Advanced Transport Reactor
System Integration	→	"First of a Kind" System Integration
Plant Controls	→	"Smart" Dynamic Plant Controls & CO_2 Management Systems

Project Cost & Cost-sharing

- Total project cost is $950 million
- $500 million (53%) -- direct project funding from DOE
- $120 million (13%) -- from DOE sequestration program DOE will use its best efforts to achieve or exceed a minimum 80/20 cost share for this R&D portion from partners outside the existing consortium
- $250 million (26%) -- direct funding is expected to be provided by the industry consortium
- $80 million (8%) -- to be provided by International partners

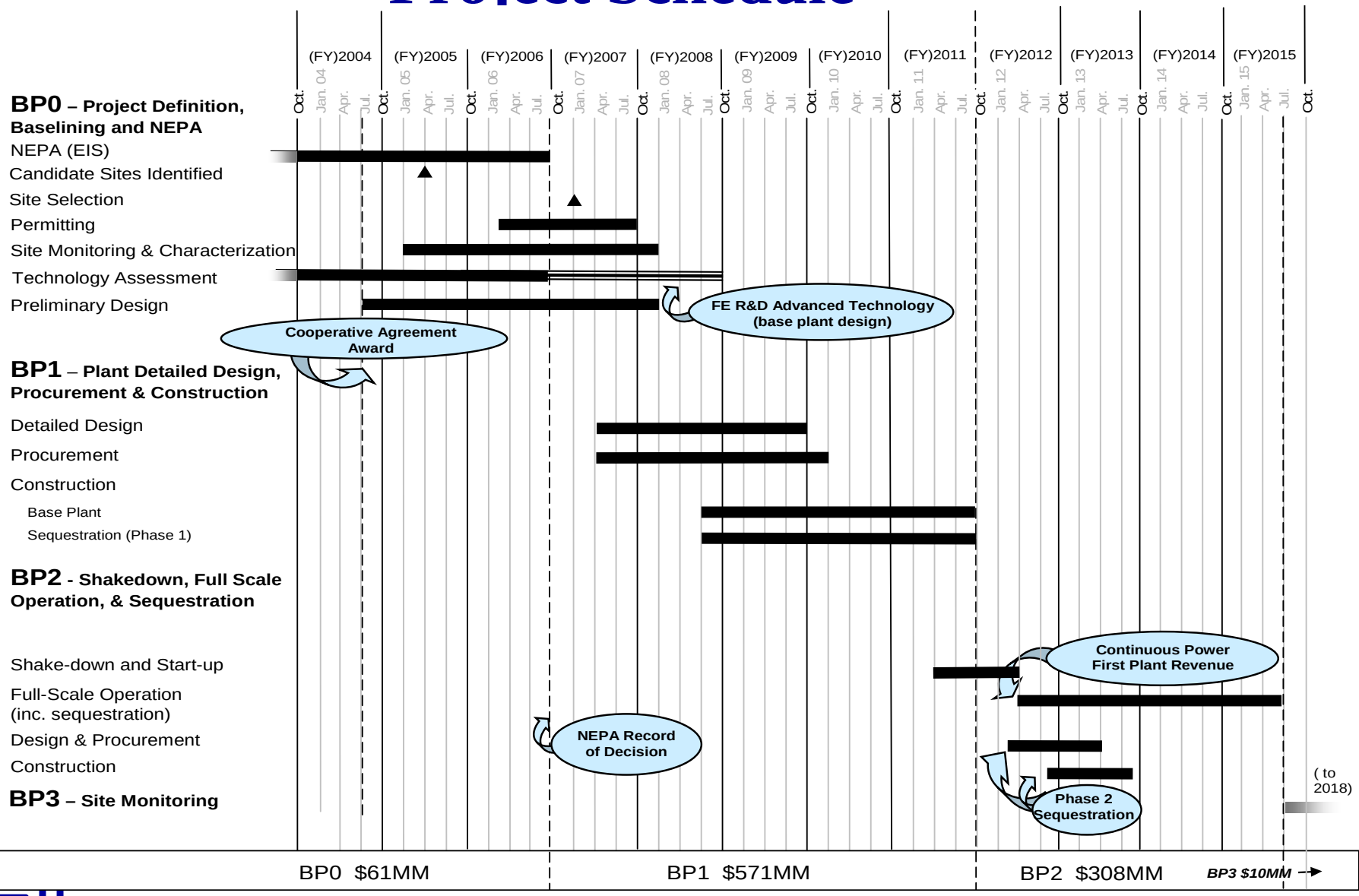
Cost Element	Estimated Costs ($M)
Plant Definition, Baselining, and NEPA	81
Plant Procurement and Construction	480
Shakedown and Full-Scale Operation	188
Sequestration (design and construction)	191
Site Monitoring	10
Total	950

Project Schedule --- Key Events



* Supporting research includes research embedded in *FutureGen* project and additional research in FE's carbon sequestration, IGCC, turbines, and fuel cell R&D programs

Project Schedule



Progress to Date

- **February 27, 2003 - Presidential announcement**
  - Received strong support from states, industry, international community and some NGOs
- **April 2003 - Project plan developed, RFI in Federal Register**
- **October 2003 - Completed departmental Critical Decision (CD)-0 process and later for CD-1 Acquisition Strategy**
- **October 2003 - Congress provided $9M for FutureGen for first year; subject to submission of FutureGen Program Plan**
- **March 4, 2004 – Submitted FutureGen Program Plan to Congress**
- **Ongoing: Internally working on negotiations strategy, drafting selection criteria, test planning, and start of NEPA and project development**

FutureGen Test Plan

- **Base plant technologies**
  - Oxygen production
  - Gasification
  - Gas separation & clean-up
  - Steam and combustion turbines
  - Alternate feedstocks (coal types)
- **Advanced cutting edge technologies** *("living laboratory")*
  - ITM oxygen production
  - Hydrogen production
  - Hydrogen combustion turbines
  - Fuel cells and hybrids
- **Sequestration system (Phase 1 & 2)**
- **Integrated Plant Performance Verification**
- **Long-term monitoring**

FY04 Activities ($9M DOE)

(Assuming an award is made to industry in late 2004)

- ***FutureGen* preliminary design** activities will be initiated.
- $2 million - Work on a draft **Environmental Impact Statement** (EIS) will be initiated.
- $1 million - Consortium will **identify candidate sites** and gather environmental information so that potential sites can be fully characterized and analyzed.
- $6 million - **'Preliminary design',** consisting of early or conceptual design and engineering activities, can proceed in advance of NEPA-related activities. NEPA precludes DOE sharing in any design and/or construction costs that extend beyond preliminary design, until after NEPA is completed. (cost shared activity)

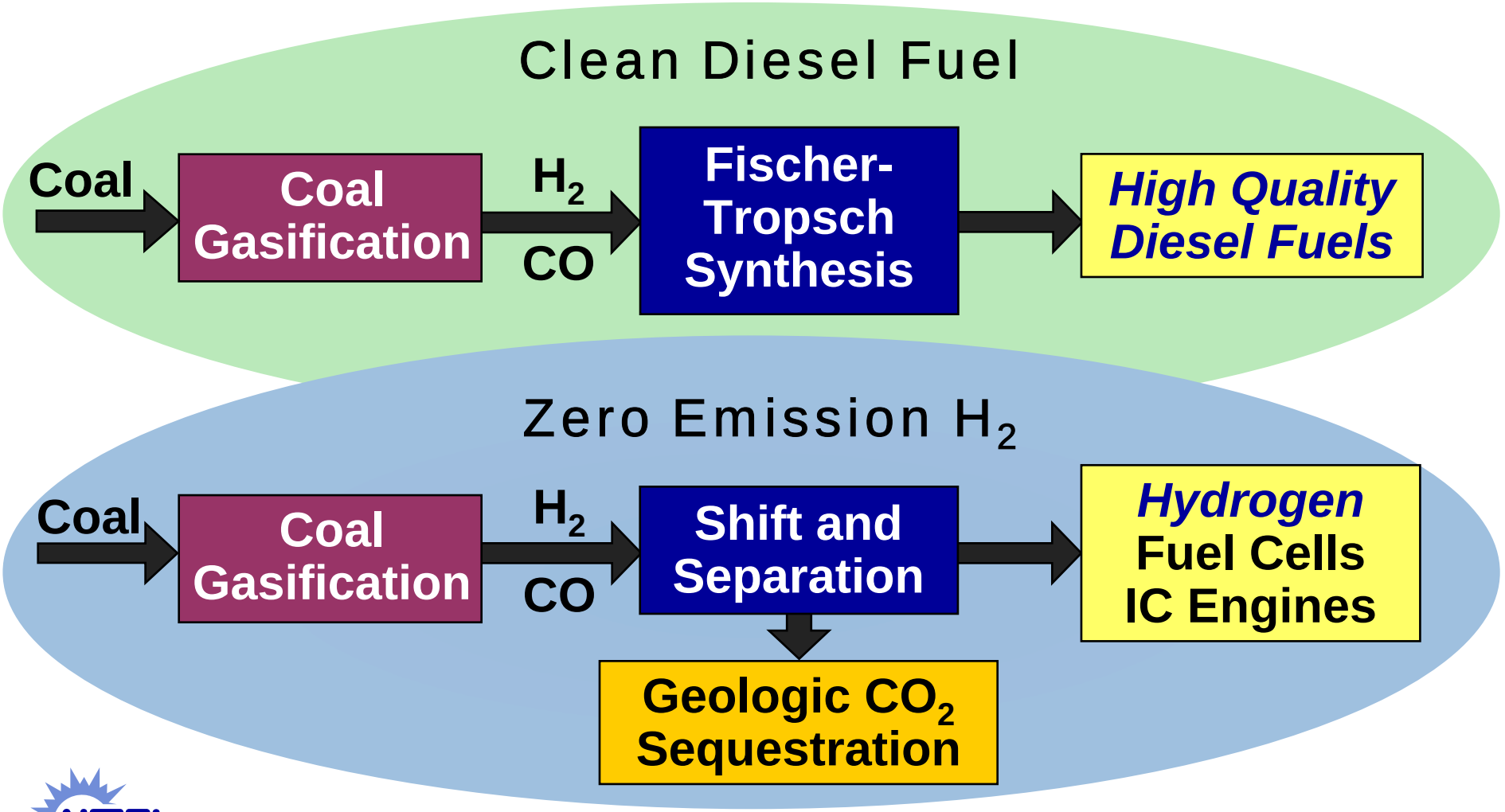
Next Steps

- **Department completed initial internal management review requirements**
  - Department may now begin negotiations with an industry partner -- forecast awarding the cooperative agreement in late 2004
- **Department will begin NEPA process**
- **High priority -- develop a set of technical siting criteria that will be used in an open, fair, and transparent competitive process**
- **Proposed sites will be qualified for consideration based on the technical and environmental criteria**
- **Qualified sites will be further evaluated on the technical criteria in parallel with the NEPA process for the project**

Key Issues

- **Consortium development awaiting outcome of DOE out-year funding commitment**
  - Impacts pre-award engagement
  - Need to identify key business issues and path forward (liability, title ownership, intellectual property, revenue treatment, site selection…)
- **Cost-sharing**
  - Industry indicated willingness to invest $200M for “missionary work” with no expectation of return on investment
- **Sequestration introduces complexities**
  - Site selection, ES&H issues, NEPA issues

FutureGen Opens Door to "Reuse" of Coal in Transportation Sector



In Summary

- **Goal: By 2015, a 60 percent efficient, zero emissions, coal-fueled hydrogen and power co-production facility is operational**

- **Benefits:**
  - Energy security
  - Early source of hydrogen for fuel cell vehicles
  - Reduced emissions of pollutants and GHGs

Visit NETL Website

www.netl.doe.gov

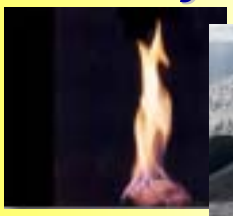
Also:

www.fe.doe.gov

Background Information

Hydrogen Production Options

Sources of Hydrogen



Fossil Fuels with Sequestration

Water

Biomass

The U.S. uses 14MM BPD of oil for transportation

14MM BPD = 220MM TPY of H2 at current efficiencies

Increasing annual coal production by 33% (330MM tons) would provide 50MMTPY of H2

50MM TPY of H2 = 50% of our current transportation requirements at Freedom Car efficiencies

Sources of Heat to Drive Reaction

Nuclear Power

Renewables

Dream Source

- Fusion
- Thermochemical
- Photochemical

Biomass photo: NREL, Calvert Cliffs Nuclear Plant

Hydrogen Production…How important is Coal?

The National Academy of Engineering recently completed a year long study of: "The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs"

Key Findings…General and those specific to coal:

- **Hydrogen could fundamentally transform the U.S. energy system; therefore a robust, ongoing hydrogen program is important**
- **Fossil Fuels will be one of the principal sources of hydrogen for the hydrogen economy…but carbon capture and storage technologies will be required**
- **The U.S. has vast coal resources…hydrogen from coal can be inexpensive…and…coal must be a significant component of R&D aimed at making very large amounts of hydrogen.**

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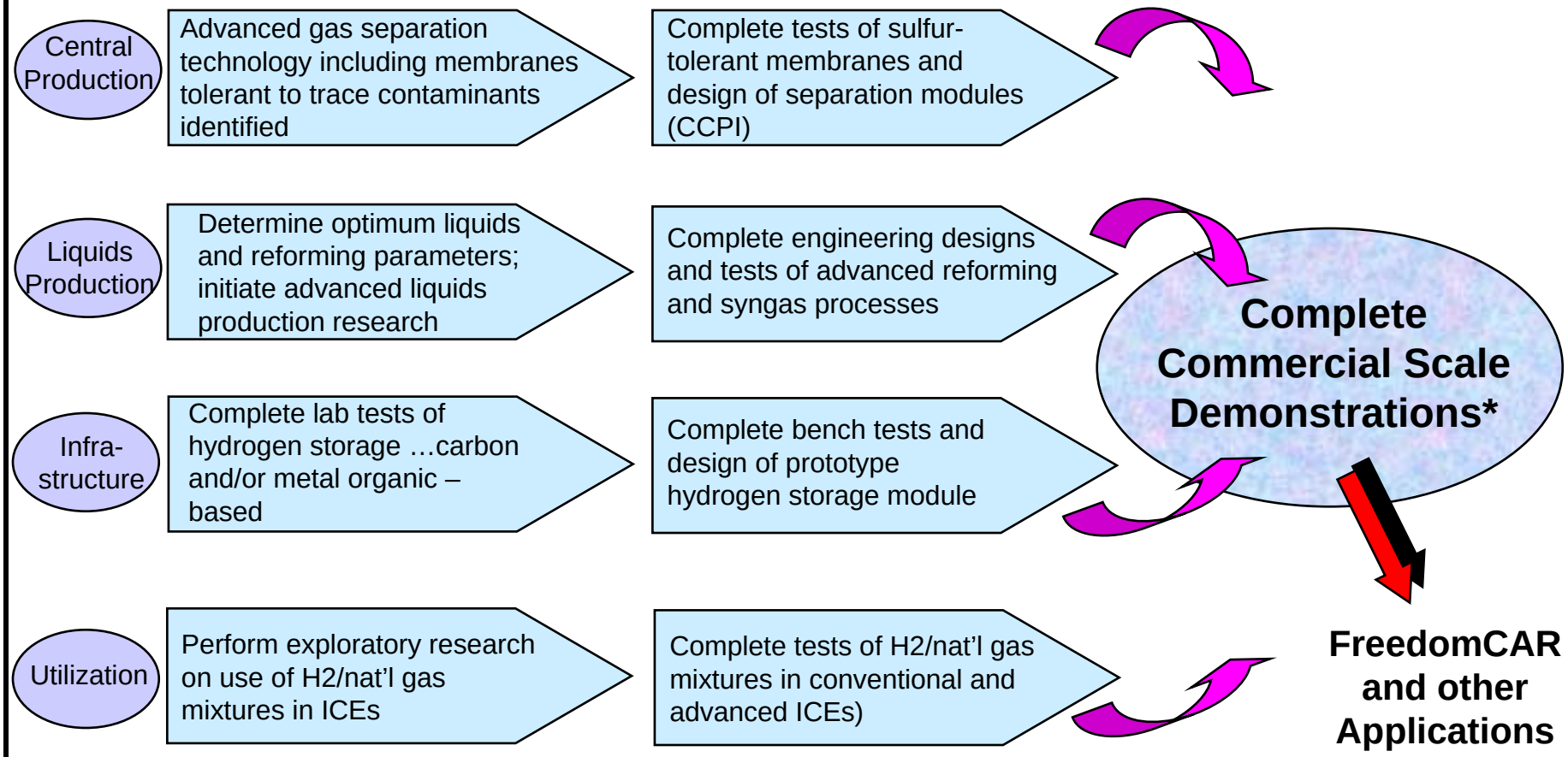
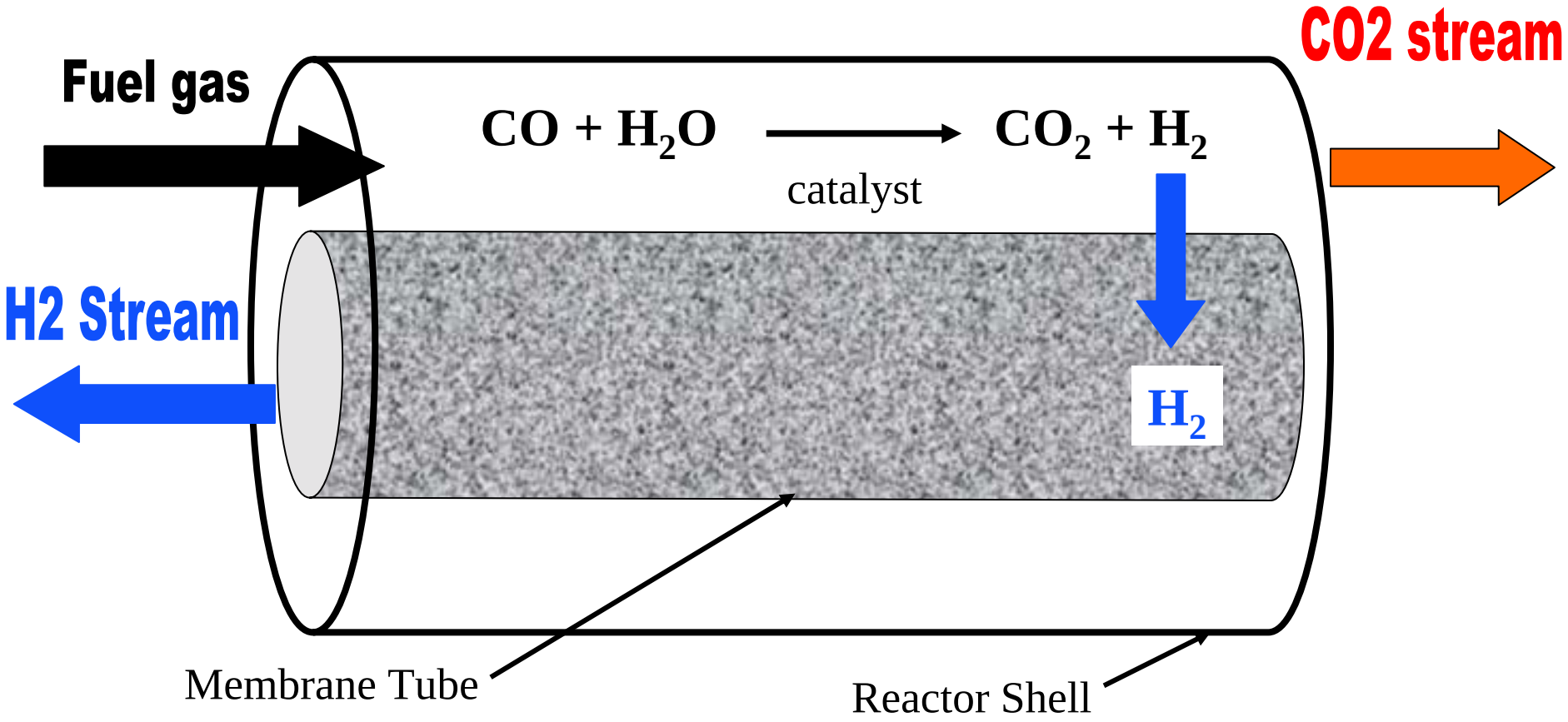
Hydrogen from Coal Program Roadmap



*** Incorporates technology being developed under the complementary Advanced Gasification and Sequestration for carbon dioxide capture and storage programs**

2005 2010 2015

Water Gas Shift - Hydrogen Separation Membrane Reactor



- Removal of hydrogen drives reaction to completion
- Carbon dioxide stream at high pressure, ready for sequestration
- Hydrogen available as a clean energy source

Gasification
Carbon Capture and Sequestration